RISK-BASED DECISION-MAKING GUIDELINES

Volume 3
Procedures for Assessing Risks

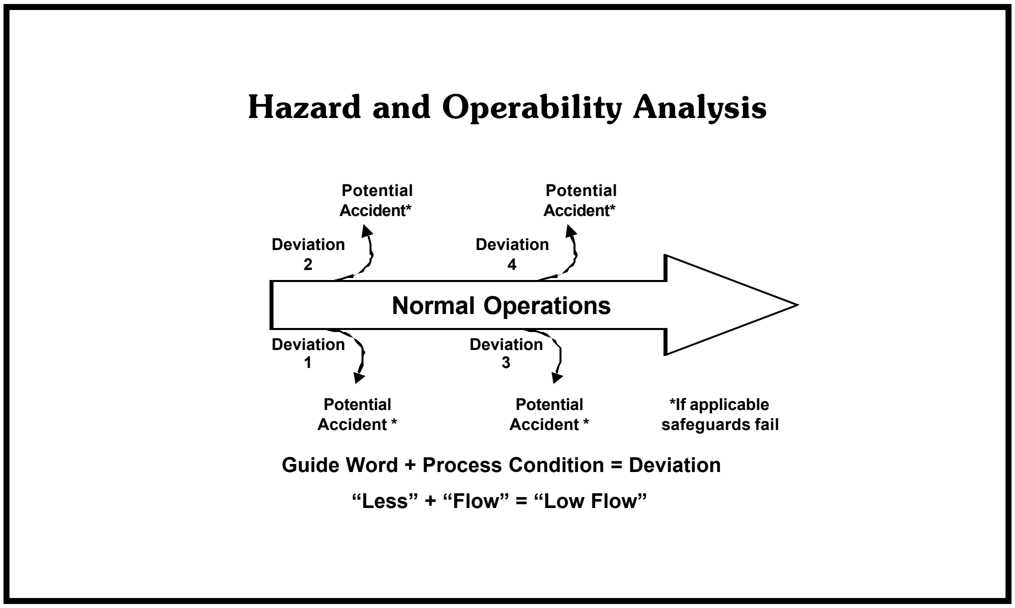
Applying Risk Assessment Tools

Chapter 10 — Hazard and Operability (HAZOP) Analysis

Chapter Contents

This chapter provides a basic overview of the hazard and operability analysis technique. It includes fundamental step-by-step instructions for using this methodology to identify possible deviations from normal operations and for ensuring that appropriate safeguards are in place to help prevent accidents. Following are the major topics in this chapter:

See an example of a hazard and operability analysis in Volume 4 in the Hazard and Operability Analysis directory under Tool-specific Resources.



Summary of Hazard and Operability (HAZOP) Analysis

The HAZOP analysis technique uses a systematic process to (1) identify possible deviations from normal operations and (2) ensure that appropriate safeguards are in place to help prevent accidents. The HAZOP technique uses special adjectives (such as "more," "less," "no," etc.) combined with process conditions (such as speed, flow, pressure, etc.) to systematically consider all credible deviations from normal conditions. The adjectives, called guide words, are a unique feature of HAZOP analysis.

Brief summary of characteristics

- A systematic, highly structured assessment relying on HAZOP guide words and team brainstorming to generate a comprehensive review and ensure that appropriate safeguards against accidents are in place
- Typically performed by a multidisciplinary team
- Applicable to any system or procedure
- Used most as a system-level risk assessment technique
- Generates primarily qualitative results, although some basic quantification is possible

Most common uses

- Used primarily for identifying safety hazards and operability problems of continuous process systems, especially fluid and thermal systems
- Also used to review procedures and sequential operations

Example HAZOP documentation

HAZOP Review of Barge Filling Operations at a Typical Small Fueling Terminal

2.0 Barge Transfer System Piping

Item	Deviation	Causes	Consequences	Safeguards	Recommendations
2.1	High flow rate	Tankerman sets the flow rate into a barge tank too high. May be because tankerman was in a hurry, not paying attention, not knowledgeable, fatigued during a long transfer operation, misled by faulty instrumentation such as a pressure gauge, failing to gauge tanks to verify filling rates, misinformed about desired flow rate, distracted by other duties (especially while filling multiple tanks), etc.	Potential to overpressurize the barge tank during filling if the relief valve is not sized to pass sufficient vapor (see deviation 3.7) Potential to create a static charge as liquid enters an empty tank (e.g., during the "cushioning" phase of transfer), possibly resulting in an internal fire or explosion within a barge tank (see deviation 3.7) Potential to fill tanks faster than the tankerman can control or to create a situation in which the valve cannot be closed, possibly resulting in a high level in a barge tank (see deviation 3.1)	Tankerman and dockman monitoring to detect problem Regulations require slow fill during cushioning and during topping off Fatigue standards apply to tankerman, but a loophole exists for "shore tankermen" who are not standing watches Modern barge tanks do not have the liquid free fall problems that older barges had	**Rec. 1** - Verify that the relief valves on the barges are sized to vent the maximum vapor flow during (1) the highest reasonable fill rate and (2) a fire on the barge that heats a cargo tank. **Rec. 2** - Explore the possibility of applying personnel fatigue standards and enforcement to marine terminal personnel. **Rec. 3** - Consider installing flow rate indicators in the filling lines. **Rec. 10** - Consider having terminal operators provide emergency transfer shutdown capability on board the barge instead of relying solely on communication with the dockman. **Rec. 11** - Consider emphasizing to terminal operators the Coast Guard's concern about extended work hours for "shore tankermen."
2.2	Low flow rate	Pump operator, dockman, or tankerman closes a valve at the wrong time Valve fails closed	Potential to cause high pressure in the line if the discharge of the pump is blocked while operating (see deviation 2.8)	Tankerman and dockman monitoring to detect problem	**Rec. 3** - Consider installing flow rate indicators in the filling lines. **Rec. 4** - Consider formalizing the use of visual cues to help tankermen easily identify valve positions (e.g., opened/closed) as they move around the deck.

Limitations of the HAZOP Technique

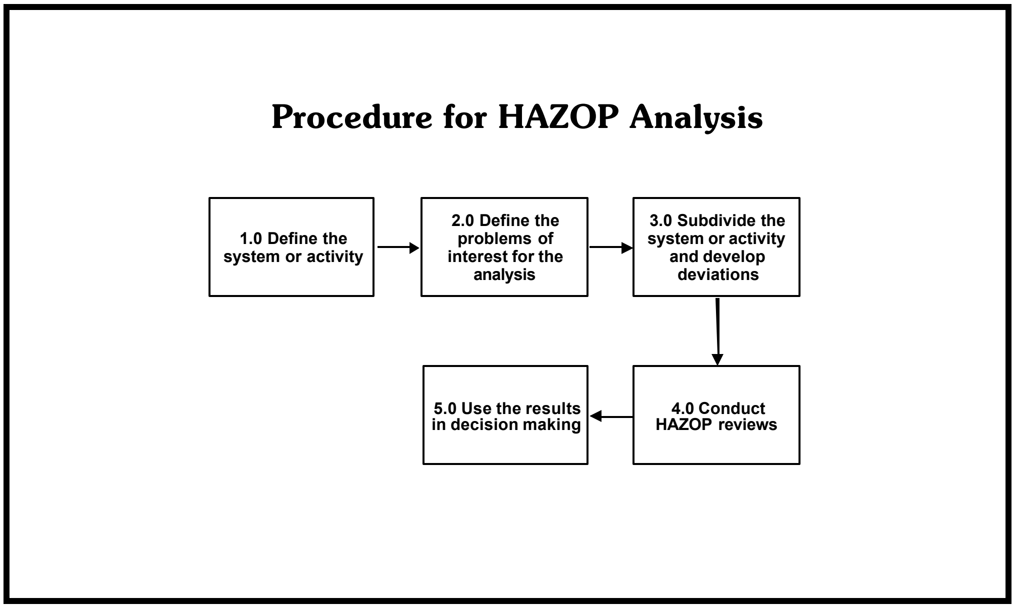
- **Requires a well-defined system or activity**
- **Time consuming**
- **Focuses on one-event causes of deviations**

Limitations of the HAZOP Technique

Requires a well-defined system or activity. The HAZOP process is a rigorous analysis tool that systematically analyzes each part of a system or activity. To apply the HAZOP guide words effectively and to address the potential accidents that can result from the guide word deviations, the analysis team must have access to detailed design and operational information. The process systematically identifies specific engineered safeguards (e.g., instrumentation, alarms, and interlocks) that are defined on detailed engineering drawings.

Time consuming. The HAZOP process systematically reviews credible deviations, identifies potential accidents that can result from the deviations, investigates engineering and administrative controls to protect against the deviations, and generates recommendations for system improvements. This detailed analysis process requires a substantial commitment of time from both the analysis facilitator and other subject matter experts, such as crew members, engineering personnel, equipment vendors, etc.

Focuses on one-event causes of deviations. The HAZOP process focuses on identifying single failures that can result in accidents of interest. If the objective of the analysis is to identify all combinations of events that can lead to accidents of interest, more detailed techniques should be used. One example would be fault tree analysis, explained in Chapter 11.



Procedure for HAZOP Analysis

The procedure for performing a HAZOP analysis consists of the following five steps:

1.0 Define the system or activity. Specify and clearly define the boundaries of the system or activity for which hazard and operability information is needed.

2.0 Define the problems of interest for the analysis. Specify the problems of interest that the analysis will address. These may include health and safety issues, environmental concerns, etc.

3.0 Subdivide the system or activity and develop deviations. Subdivide the system or activity into sections that will be individually analyzed. Then apply the HAZOP guide words that are appropriate for the specific type of equipment in each section.

4.0 Conduct HAZOP reviews. Systematically evaluate each deviation for each section of the system or activity. Document recommendations and other information collected during the team meetings, and assign responsibility for resolving team recommendations.

5.0 Use the results in decision making. Evaluate the recommendations from the analysis and the benefits they are intended to achieve. The benefits may include improved safety and environmental performance or cost savings. Determine implementation criteria and plans.

The following pages describe each step in detail.

1.0 Define the system or activity

- **Intended functions**
- **Boundaries**

1.0 Define the system or activity

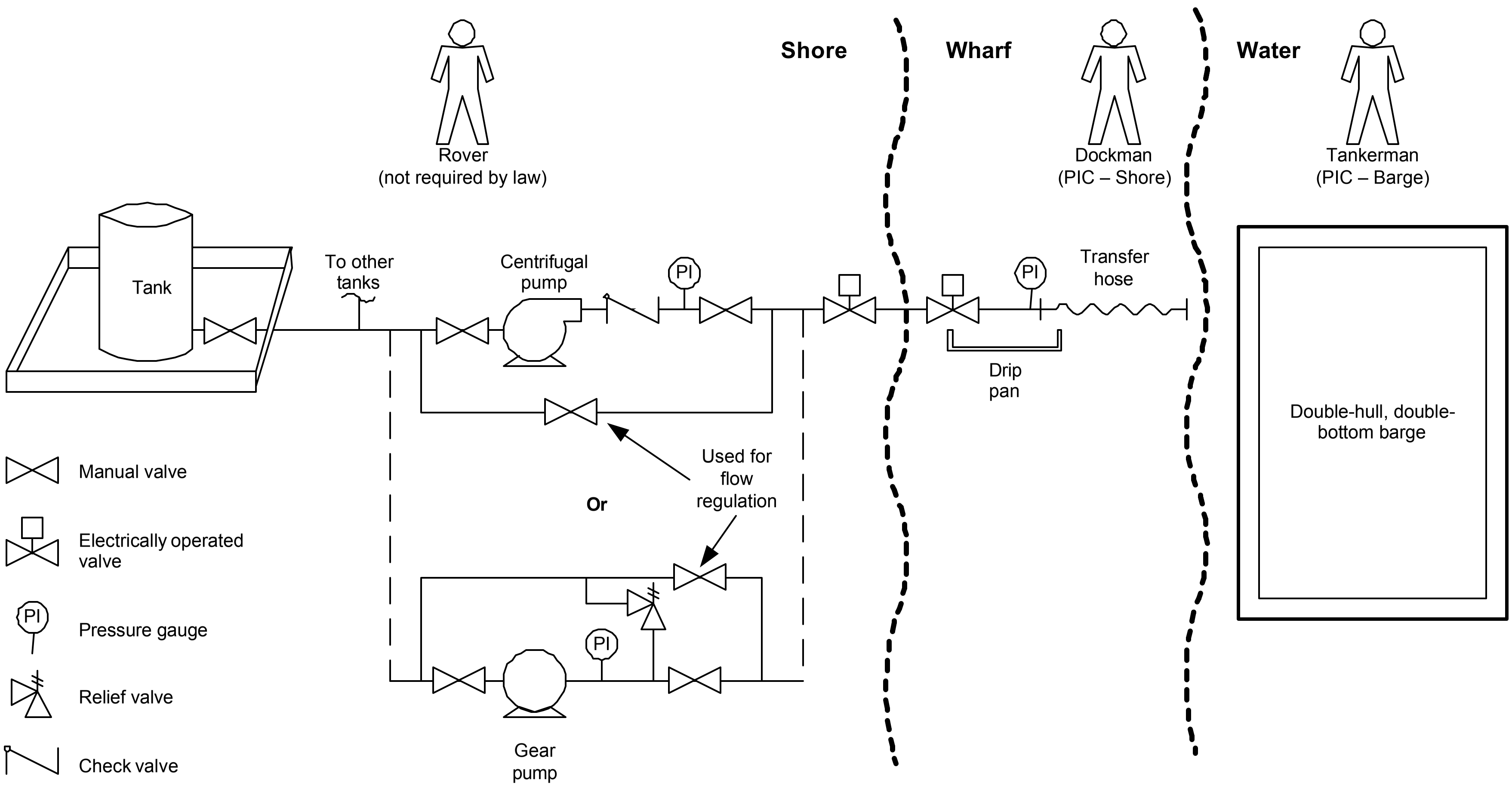
Intended functions. Because all HAZOP analyses are concerned with ways in which a system can deviate from normal operations, clearly defining the intended functions for a system or activity is an important first step. It is important to clearly document this step for the HAZOP analysis.

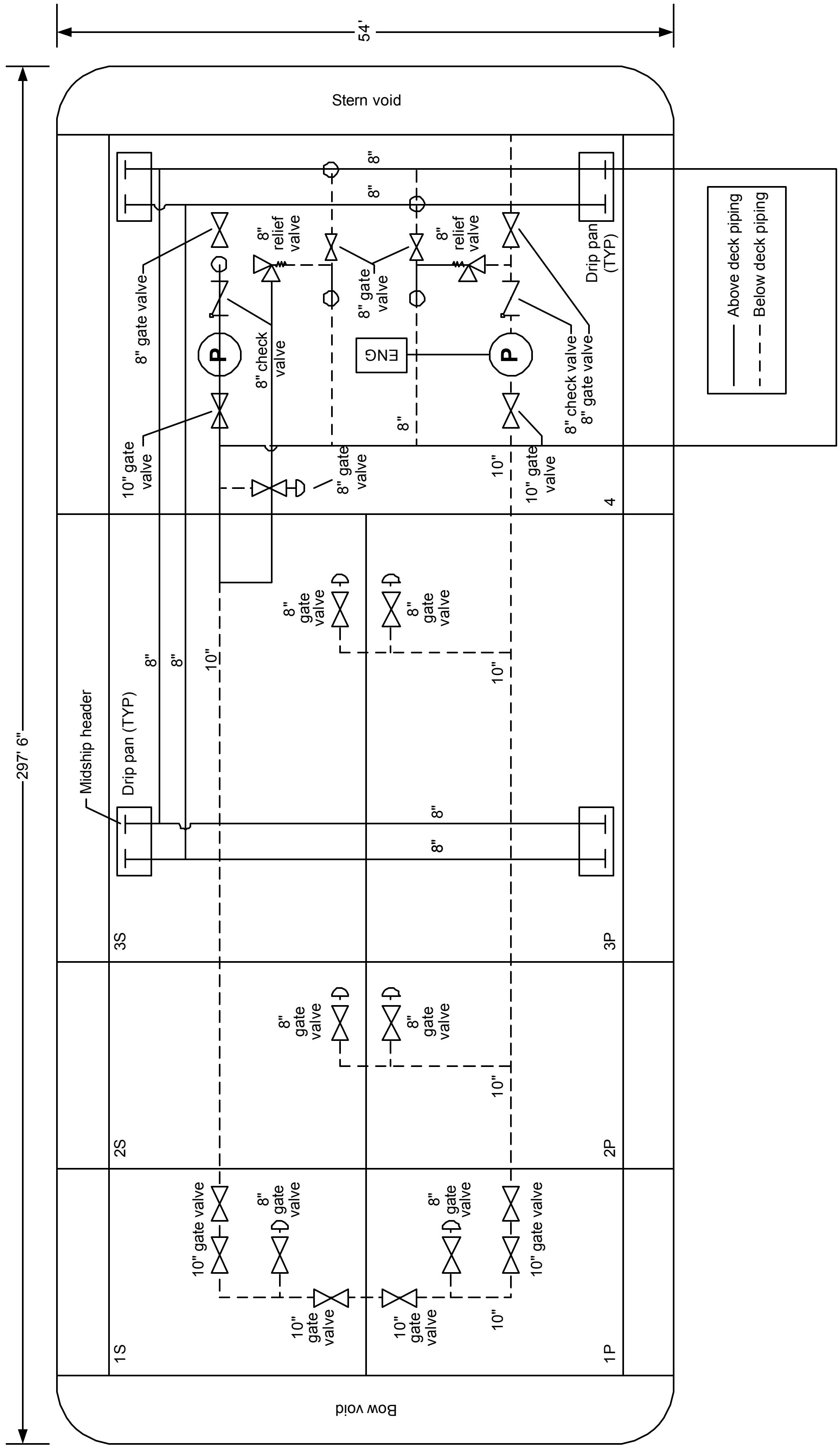
Boundaries. Few systems or marine activities operate in isolation. Most are connected to or interact with others. By clearly defining the boundaries of a system or activity, analysts can avoid (1) overlooking key elements at interfaces and (2) penalizing a system or activity by associating other equipment or operations with the subject of the study. This is especially true of boundaries with support systems, such as electric power and compressed air, or boundaries with other vessel activities, such as cargo loading and unloading. It is also important to clearly define the extent to which support systems will be analyzed.

Example

The figures on the next two pages define the boundaries for a HAZOP analysis of fuel barge filling operations at small marine terminals. The procedure that follows describes the intended transfer operation.

Flow diagram for fuel barge filling operations at small marine terminals





Piping and instrumentation diagram of a fuel barge

Because the team chose not to address the barge mooring operation in preparation for filling, this analysis assumes, as an initial condition, that the barge is already moored and waiting for filling to begin. The team listed the following typical steps for performing a barge filling operation:

1. Check the physical position of the barge for alignment with the facility equipment
2. Check that the barge is properly secured
3. Review and complete the Document of Inspection (DOI)
4. Make the hose connections
5. Agree (dockman and tankerman) to begin the transfer
6. Open valves and start the pump (if needed) to begin the transfer at a slow flow rate, allowing the tankerman to check for proper filling and avoiding splash filling into an empty tank
7. Adjust valves and the pump for the full flow rate agreed upon by the dockman and tankerman
8. Adjust valves on the barge as necessary to control filling of the various tanks on the barge. Do this to avoid overfilling, to protect the integrity of the vessel as the load changes, and to achieve the proper trim for the subsequent transit.
9. Adjust valves and the pump for “topping off” each of the tanks at a slow flow rate to avoid overfilling
10. Shut off the pump (if used) and close valves. Close valves closest to the storage tanks first so that liquid can drain into the barge, leaving the piping and hose mostly empty.
11. Disconnect the empty hose on the barge side, allowing any residual liquid to drain into the drip pan at the barge
12. Place a blank flange on the open end of the hose
13. Move the free end of the hose to the drip pan on the wharf, taking care not to drip any product into the water
14. Complete documentation, including the Oil Record Book for the barge

The Coast Guard regulates these and other types of transfer operations under the published requirements in 33 CFR 154, 155, and 156.

2.0 Define the problems of interest for the analysis

- Safety problems
- Environmental issues
- Economic impacts

2.0 Define the problems of interest for the analysis

Safety problems. The analysis team may be asked to look for ways in which improper performance of a marine activity or failures in a hardware system may result in personnel injury. These injuries may be caused by many mechanisms, including the following:

- Vessel collisions or groundings
- Drowning
- Exposure to high temperatures (e.g., through steam leaks)
- Fires or explosions

Environmental issues. The analysis team may be asked to look for ways in which the conduct of a particular marine activity or the failure of a system may adversely affect the environment. These environmental issues may be caused by many mechanisms, including the following:

- Discharge of material into the water, intentional or unintentional
- Equipment failures, such as seal failures, that result in a material spill
- Overutilization of a marine activity resulting in a disruption of the ecosystem

Economic impacts. The analysis team may be asked to look for ways in which the improper conduct of a particular marine activity or the failure of a system may have adverse economic impacts. These economic risks may be categorized in many ways, including the following:

- Business risks, such as vessels detained at port, contractual penalties, lost revenue, etc.

- Environmental restoration costs
- Replacement costs, such as the cost of replacing damaged equipment

A particular analysis may focus only on events above a certain threshold of concern in one or more of these categories.

Example for the barge filling HAZOP

The project team defined the problems of interest for this analysis as:

- Oil spill into the water or onto the ground, outside of secondary containment, during a barge filling operation
- Fire or explosion involving the product during a barge filling operation

For this brief demonstration workshop, the team chose not to address other possible consequences of interest, such as the following:

- Various types of injuries to workers not directly associated with the consequences listed above. These injuries can result from physical hazards, electrical hazards, thermal hazards, etc.
- Product contamination issues
- Equipment damage not directly associated with the consequences listed above

3.0 Subdivide the system or activity and develop deviations

Define sections

↓

Develop credible deviations

↓

Develop HAZOP worksheets

3.0 Subdivide the system or activity and develop deviations

Before the HAZOP team meets, the leader and scribe should conduct several activities to help make the team meeting time more efficient. These pre-meeting activities include the following:

Define sections. Sections are simply discrete parts of a process such as a section of piping a tank, etc. The leader and scribe must divide the system equipment into *sections* in order to properly apply the HAZOP technique. The leader must balance two competing factors: (1) the HAZOP team may overlook important deviations if the sections are too large and (2) the HAZOP team will waste time examining the same issues repeatedly if the sections are too small.

Develop credible deviations. Deviations are upset conditions compared to normal operations. The structured approach of the HAZOP analysis is accomplished by using special guide words. Deviations are derived in the following manner:

Guide Word + System Parameter = Deviation

The type of system section, such as piping or tank, will determine the applicable system parameters to be analyzed for that section. By combining guide words with the applicable process parameter, the leader develops a list of credible deviations to analyze during the study.

Develop HAZOP worksheets. The scribe is responsible for documenting a significant amount of information during the study. Preparing specialized worksheets before the meeting for each type of section and for the credible deviations will help the scribe more efficiently organize the HAZOP information collected during the meetings.

The following subsections describe these terms and steps in more detail.

Defining sections

- **Appropriate for the HAZOP objectives**
- **Small enough to avoid overlooking deviations**
- **Consistent level of detail**

3.1 Guidelines for defining sections for a HAZOP analysis

Three *general considerations* should guide the leader when dividing a system into sections:

Define sections appropriate for the HAZOP objectives. A HAZOP analysis investigating the potential for *reportable* material releases into the waterway may require consideration of many more system sections than a HAZOP analysis investigating material releases large enough to create long-term chronic health risks.

Define sections small enough to include all important deviations. It is far better to discover that a section has deviations that are the same as another section than to miss an important deviation. Experienced leaders will quickly recognize the unnecessary section and move the team on. Inexperienced leaders will learn to recognize unnecessary sections, but by defining small sections, they will be less likely to miss an important deviation, while gaining experience as a leader.

Define sections at a consistent level of detail. The HAZOP leader should not define every sample connection and instrument line as sections for one part of a process, while defining a shoreside tank farm as a single section elsewhere in the process. If the HAZOP objectives require sectioning the unit to a certain level of detail, then that same level should be applied throughout the analysis.

Dividing a system or activity into sections and selecting appropriate deviations are interrelated activities. The suggested deviations for sections presume these guidelines for sectioning have been followed. Specific circumstances will dictate exceptions to these sectioning guidelines and to the guidelines for selecting deviations. In most situations, following these guidelines will produce process sections that can be thoroughly reviewed by the HAZOP team with a minimum risk of overlooking important deviations. The guidelines are as follows:

3.1.1 Beginning guidelines (for leaders with less experience)

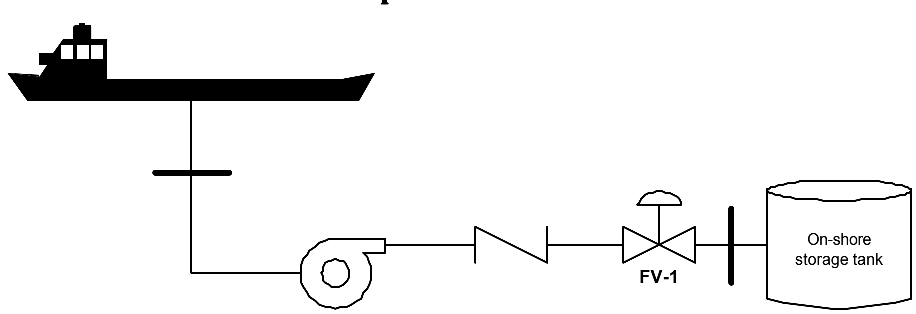
- Define each major component as a section. Usually, anything in which a fluid level is maintained should be considered a major component.
- Define one line section between each major component
- Define additional line sections for each branch off the main flow
- Define a section at each connection to existing equipment

3.1.2 Advanced guidelines

Experienced leaders will recognize that the beginning guidelines often produce some "unnecessary" process sections. The following are supplemental guidelines that will help experienced leaders reduce duplication:

- Define only one section for equipment in identical service. The most common situation is multiple pumps or heat exchangers. **CAUTION:** Pumps in different service with a "common" spare must be treated separately, and additional deviations such as misdirected flow must be considered. Usually, the HAZOP team must explicitly consider operation of the common spare as a special operating mode if the common spare has characteristics different from the pump it replaces. These characteristics may include higher pressure, larger flow, etc.
- Define only one line section for a series of components if there are no other flow paths. Line sections are necessary to cover deviations such as the low or high temperature caused by a heat exchanger or the low or high pressure caused by a pump. As illustrated in the figure below, only one line section is necessary between the vessel and the on-shore storage tank.

Example line section



- Define only one additional line section if there are alternate flow paths, regardless of how many branches there are. However, add misdirected and reverse flow deviations specifically for each branch. As illustrated in the figure below, assuming flow through FV-1 is the desired path, define Section B as the manifold with the following misdirected or reverse flow deviations:

  Misdirected flow from vessel to FV-2

  Misdirected flow from vessel to FV-3

  Reverse flow from FV-1 to FV-2

  Reverse flow from FV-1 to vessel

  Reverse flow from FV-2 to vessel

  Reverse flow from FV-2 to FV-3

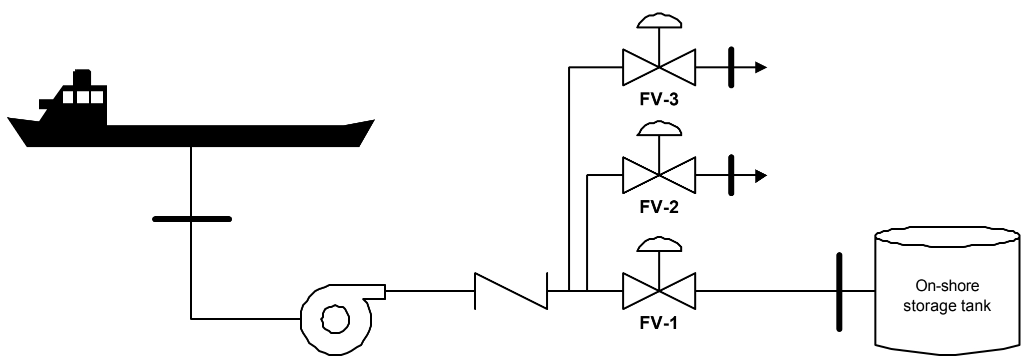
  Reverse flow from FV-2 to storage tank

  Reverse flow from FV-3 to FV-1

  Reverse flow from FV-3 to FV-2

  Reverse flow from FV-3 to storage tank

Example additional line section



- Define line sections between major equipment items even if there are no single active components, such as control valves, that could cause flow deviations (high/low/no/reverse/misdirected). In circumstances like this, you can usually skip those deviations because they are not particularly meaningful; however, deviations such as high or low temperature, high or low pressure, and contaminants are usually important.

Do not define process sections for existing equipment that is “upstream” of new or modified equipment. Address malfunctions of such upstream equipment as causes of deviations in the new or modified equipment. However, this will usually require that the list of deviations for the first piece of new or modified equipment be expanded.

Example sections for the barge filling HAZOP

To facilitate the HAZOP analysis, the team divided the system into the following three distinct sections:

- **Section 1: Shoreside Transfer System.** A line section from the storage tanks to the barge's piping manifold, including any pump stations, shoreside flow control valves and isolation valves, and the transfer hose
- **Section 2: Barge Transfer System Piping.** A line section from the transfer hose to the barge's cargo tanks, including the barge's manual valves
- **Section 3: Barge Cargo Tanks.** A vessel section representing each of the cargo tanks on the barge, including the tanks and associated gauging devices

Develop credible deviations:
the guide word approach

Guide Word + System Condition = Deviation

Guide Word	*System Condition*
No (not)	Flow
More (high, long)	Pressure
Less (low, short)	Temperature
As Well As	Level
Part Of	Time
Reverse	Composition
Other Than	… others …

3.2 Develop credible deviations

Deviations are developed in the HAZOP technique by applying guide words to system conditions. The following table lists the HAZOP guide words and typical system conditions:

Guide Word	*System Condition*
No (not)	Flow
More (high, long)	Pressure
Less (low, short)	Temperature
As Well As	Level
Part Of	Time
Reverse	Composition
Other Than	… others …

To help ensure thorough consideration of hazards, additional general deviations are also applied, as shown in the following table:

General Deviations	
Leak/Rupture	Sampling
Loss of Containment	Testing
Corrosion/Erosion	Maintenance
Relief	Startup
Reaction	Shutdown
Ignition Source	Service Failure

HAZOP Deviation Guide

Guide Words / Process Variables	No, Not, None	Less, Low, Short	More, High, Long	Part of	As Well As, Also	Other Than	Reverse
Flow	No Flow	Low Rate, Low Total	High Rate, High Total	Missing Ingredient	Misdirection, Impurities	Wrong Material	Backflow
Pressure	Open to Atmosphere	Low Pressure	High Pressure	———	———	———	Vacuum
Temperature	Freezing	Low Temperature	High Temperature	———	———	———	Auto-refrigeration
Level	Empty	Low Level	High Level	Low Interface	High Interface	———	———
Agitation	No Mixing	Poor Mixing	Excessive Mixing	Mixing Interruption	Foaming	———	Phase Separation
Reaction	No Reaction	Slow Reaction	Runaway Reaction	Partial Reaction	Side Reaction	Wrong Reaction	Decomposition
Time, Procedure	Skipped or Missing Step	Too Short, Too Little	Too Long, Too Much	Action Skipped	Extra Action (Shortcuts)	Wrong Action	Out of Order, Opposite
Speed	Stopped	Too Slow	Too Fast	Out of Synch	———	Web or Belt Break	Backward
Special	Utility Failure	External Leak	External Rupture	Tube Leak	Tube Rupture	Startup, Shutdown, Maintenance	———

Other Variables: Concentration, Viscosity, pH, Static, Voltage, Current, etc.

Example sections for the barge filling HAZOP

For each section, the team developed a list of possible deviations (off-normal conditions) that could develop and cause consequences of interest. Consistent with the HAZOP analysis approach, the team developed this list of deviations by combining "guide words" (essentially a standard list of adjectives) with normal process parameters for sections of the system. The following table lists the deviations that the team considered for each section and illustrates how the team developed the list.

Deviations for Each Section

Deviation	Basis for Each Deviation*	Section 1	Section 2	Section 3
High flow	"More" + "Flow"	X	X	
Low/no flow	"Less" + "Flow" "No" + "Flow"	X	X	
Reverse flow	"Reverse" + "Flow"	X	X	
Misdirected flow	"Other than" + "Flow"	X	X	
High level	"More" + "Level"			X
Low/no flow	"Less" + "Level" "No" + "Level"			X
High temperature	"More" + "Temperature"	X	X	X
Low temperature	"Less" + "Temperature"	X	X	X
High pressure	"More" + "Pressure"	X	X	X
Low pressure	"Less" + "Pressure" "No" + "Pressure"	X	X	X
Contamination	"Other than" + "Concentration"	X	X	X
Leak/rupture	"No" + "Containment"	X	X	X

*Basis of each listed deviation is presented as "Guide Word"+"Process Parameter." Other combinations of guide words and process parameters were considered, but only those combinations that were meaningful or useful to the team are listed in the table.

Develop HAZOP worksheets

- **Section**
- **Intent**
- **Deviation**
- **Causes**
- **Accidents**
- **Safeguards**
- **Recommendations**

3.3 Develop HAZOP worksheets

During the meeting, the scribe will document the HAZOP information on worksheets. The following information will be documented for the HAZOP:

Section. Name of the section. This is usually documented by the leader and scribe before the meeting.

Intent. The team will describe the design intent for the particular HAZOP section being analyzed. Declaring this intent is important, because the remainder of the discussion will focus on ways that the process can deviate from this intent. An example of a design intent for a vessel unloading line may be: "Transfers crude oil from vessel cargo tanks to the shoreside storage tank using flow control."

Deviation. Specific deviation that will be analyzed by the team

Causes. Credible causes for the deviation as postulated by the HAZOP team

Accidents. Ultimate accidents of the deviation as postulated by the HAZOP team. These should correspond to the problems of interest that were defined as an objective for the study.

Safeguards. Engineering and administrative controls that protect against the deviations. These safeguards can either help prevent the cause from occurring or help mitigate the severity of the accidents should the cause occur.

Recommendations. Suggestions made by the team to help reduce the risk associated with specific issues if the team is not comfortable with the level of safeguards that currently exist

The table on the following page includes an example HAZOP worksheet. Completed HAZOP worksheets are presented later in this section.

Example HAZOP worksheet

HAZOP Review of Barge Filling Operations at a Typical Small Fueling Terminal					
1.0 Line from a Storage Tank to the Barge Manifold (including the Transfer Hose)					
Item	**Deviation**	**Causes**	**Consequences**	**Safeguards**	**Recommendations**
1.1	High flow rate				
1.2	Low/no flow rate				

4.0 Conduct HAZOP reviews

- **Introduce the team members**
- **Describe the HAZOP approach**
- **Conduct the analysis**

4.0 Conduct HAZOP reviews

The systematic analysis process of the HAZOP technique is conducted in the following manner:

Step 1. Introduce the team members.

Step 2. Describe the HAZOP approach.

Step 3. Identify Section 1.

Step 4. Ask the team to define the design intent of Section 1.

Step 5. Apply the first deviation to Section 1, and ask the team "What are the consequences of this deviation?"

Allow time for the team to consider the system upset. Some prompting may be necessary to get the discussion going.

If no accidents of interest are identified, go back to the beginning of Step 5 and apply the next deviation. If there are no credible accidents, there is no need for the team to investigate causes or safeguards.

Step 6. After the team has exhausted its analysis of accidents, prompt the team to identify all of the causes of the deviation.

Step 7. Identify the engineering and administrative controls that protect against the system upset. Remember, these controls can be either preventive (i.e., they help prevent the upset from occurring) or mitigative (i.e., they help reduce the severity of the accidents associated with the upset if it occurs).

Step 8. If the team is concerned that the level of protection is not adequate for the particular system upset, then the team should develop recommendations to investigate alternatives. Level of protection includes the number, type, and pedigree of the safeguards.

Step 9. Summarize the information collected for this deviation.

Step 10. Repeat Steps 5 through 9 for the remaining deviations associated with this section.

Step 11. Repeat Steps 3 through 10 for the remaining sections.

Example of documentation from the barge filling HAZOP

HAZOP Review of Barge Filling Operations at a Typical Small Fueling Terminal

1.0 Line from a Storage Tank to the Barge Manifold (Including the Transfer Hose)

Item	Deviation	Causes	Consequences	Safeguards	Recommendations
1.1	High flow rate	Pump operator sets the flow rate too high. May be because operator was in a hurry, not paying attention, not knowledgeable, fatigued during a long transfer operation, misled by faulty instrumentation such as a pressure gauge, failing to gauge tanks to verify filling rates, misinformed about desired flow rate, distracted by other duties, etc.	Potential to overpressurize the barge tank during filling if the relief valve is not sized to pass sufficient vapor (see deviation 3.7) Potential to create a static charge as liquid enters an empty tank (e.g., during the "cushioning" phase of transfer), possibly resulting in an internal fire or explosion within a barge tank (see deviation 3.7) Potential movement or vibration of a hose, possibly contributing to a leak or rupture (see deviation 1.10) Potential to fill tanks faster than the tankerman can control or to create a situation in which the valve cannot be closed, possibly resulting in a high level in a barge tank (see deviation 3.1)	Tankerman and dockman monitoring to detect problem Shore facility piping system is grounded to barge manifold, which should help reduce static accumulation across the hose Regulations require slow fill during cushioning and during topping off Modern barge tanks do not have the liquid free fall problems that older barges had	**Rec. 1** - Verify that relief valves on the barges are sized to vent maximum vapor flow during (1) the highest reasonable fill rate and (2) a fire on the barge that heats a cargo tank. **Rec. 2** - Explore the possibility of applying personnel fatigue standards and enforcement to marine terminal personnel. **Rec. 3** - Consider installing flow rate indicators in the filling lines.
1.2	Low/no flow rate	Pump operator, dockman, or tankerman closes a valve at the wrong time Valve fails closed	Potential to cause high pressure in the line if the discharge of the pump is blocked while operating (see deviation 1.7)	Tankerman and dockman monitoring to detect problem	**Rec. 3** - Consider installing flow rate indicators in the filling lines. **Rec. 4** - Consider formalizing the use of visual cues to help tankermen easily identify valve positions (e.g., opened/closed) as they move around the deck.
1.3	Misdirected flow				

Example of documentation from the barge filling HAZOP (cont.)

HAZOP Review of Barge Filling Operations at a Typical Small Fueling Terminal					
1.0 Line from a Storage Tank to the Barge Manifold (Including the Transfer Hose) (cont.)					
Item	**Deviation**	**Causes**	**Consequences**	**Safeguards**	**Recommendations**
1.4	Reverse flow	No credible causes (maximum level in barge tanks is below facility grade level)		Typical arrangement has a check valve at the discharge of the loading pump if a centrifugal pump is used	
1.5	High temperature		No consequences of interest		
1.6	Low temperature		No consequences of interest		
1.7	High pressure	Low/no flow rate because of a deadheaded pump (see deviation 1.2) Thermal expansion of liquid isolated between closed valves	Potential leak or rupture of the piping (see deviation 1.10)	Regulations specify the maximum allowable pressure for transfer operations Relief valve at the discharge of gear pumps (typically installed) Lines typically drain to barge tanks before valves are closed, minimizing the potential for isolating liquid-full lines	**Rec. 5** - Verify that a relief valve is required at the discharge of positive displacement pumps (e.g., gear pumps) that are capable of damaging the piping system (including the transfer hose) if deadheading occurs.
1.8	Low pressure		No consequences of interest		
1.9	Contamination	No credible causes (these types of facilities do not typically handle incompatible materials)			

Example of documentation from the barge filling HAZOP (cont.)

HAZOP Review of Barge Filling Operations at a Typical Small Fueling Terminal					
1.0 Line from a Storage Tank to the Barge Manifold (Including the Transfer Hose) (cont.)					
Item	**Deviation**	**Causes**	**Consequences**	**Safeguards**	**Recommendations**
1.10	Leak/rupture	High pressure (see section 1.7) Improper maintenance or assembly Corrosion of piping Gasket failures in pumps or piping External impacts Vent or drain valves leaking or open Valves or gauges leaking Vibration or improperly supported hoses or piping (including vibration caused by a high flow; see deviation 1.1) Saltwater corrosion of hose or fittings Movement of the barge, damaging a hose (caused by wake or suction from passing vessels, contact with other vessels, etc.) Improper handling of hoses after transfers, allowing oil to drip into the water	Spill of oil onto the ground or into the water; potential for a fire or explosion	Annual pressure testing of hoses and piping system Material of construction specifications Regulations require proper mooring Tankerman and dockman monitoring to detect problems (mooring conditions and equipment conditions) Visual inspections before transfers as part of DOI Regulations require emergency procedures Typical facilities have emergency shutdown systems that close valves and stop the transfer pump Multiple isolation points exist at many facilities (valves at the dock and at the tank are required) Hose ends placed over drip pans after transfers and then sealed with a blind flange	**Rec. 6** - Consider requiring emergency shutdown actuation triggered by barge movement. **Rec. 7** - Consider requiring facilities to build into the shore facility piping system a designated "breakaway point" in case of barge movement. **Rec. 8** - Consider requiring terminal operators to furnish the Coast Guard with piping inspection certifications. **Rec. 9** - Consider revising secondary containment requirements at wharfs to focus on reliable containment, not just a certain capacity.

5.0 Use the results in decision making

- **Judge acceptability**
- **Identify improvement opportunities**
- **Make recommendations for improvements**
- **Justify allocation of resources for improvements**

5.0 Use the results in decision making

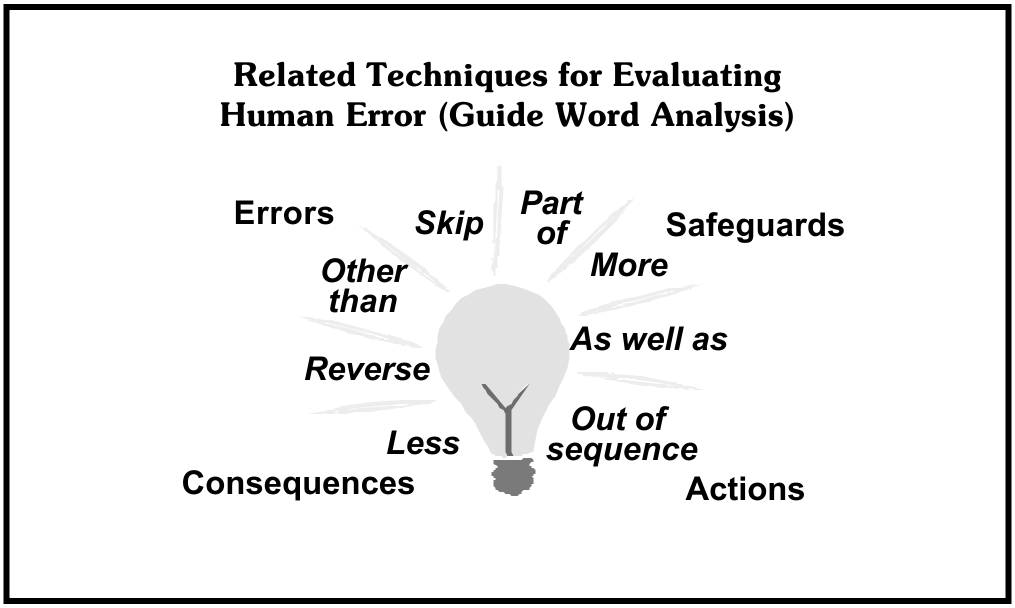
Judge acceptability. Decide whether the estimated performance for the system or activity meets an established goal or requirement.

Identify improvement opportunities. Identify the elements of the system or activity that are most likely to contribute to future reliability-related problems. These are the items with the largest percentage contributions to the pertinent reliability-related factors of merit.

Make recommendations for improvements. Develop specific suggestions for improving future system or activity performance, including any of the following:

- Equipment modifications
- Procedural changes
- Administrative policy changes such as planned maintenance tasks, personnel training

Justify allocation of resources for improvements. Estimate how implementation of expensive or controversial recommendations for improvement will affect future performance. Compare the economic benefits of these improvements to the total life-cycle costs of implementing each recommendation.



Related Techniques for Evaluating Human Error (Guide Word Analysis)

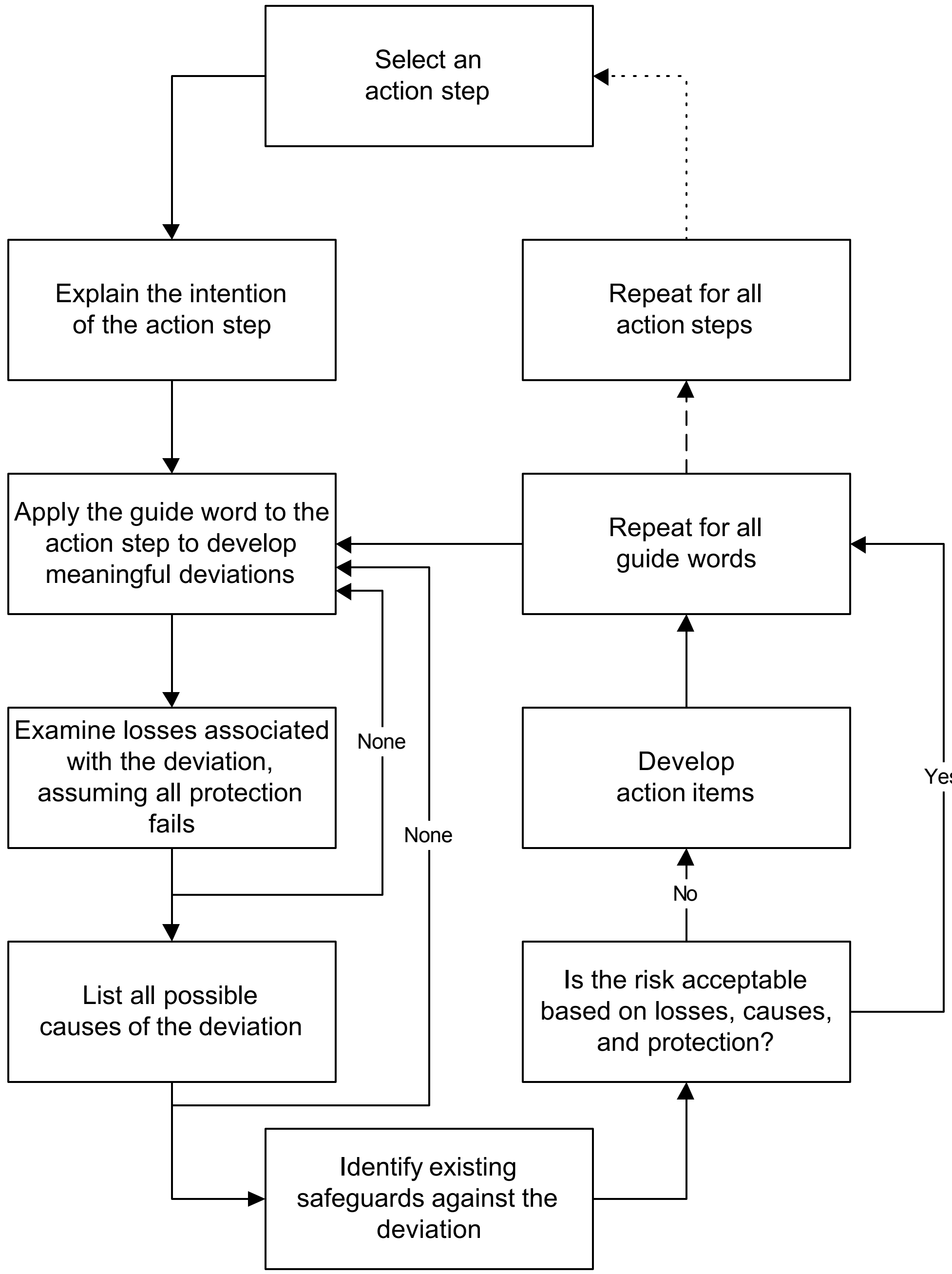
Guide word analysis encompasses a group of techniques in which guide words are applied to intended actions to identify and assess the significance of human errors. One of the more common techniques is called worker and instruction safety evaluation (WISE). More information on this specific technique is described in Volume 4 of these *Guidelines*.

Most common uses

Guide word analysis can be integrated as a natural extension of traditional task assessments or procedure development. Typically, the most critical operations to assess for potential human error are those that are nonroutine or new. A guide word analysis is performed before or during training or retraining, so that the results of the analysis can be fed into the training in the form of precautions, warnings, and troubleshooting guidelines. There may also be recommendations to modify the human-machine interface or to provide additional protection.

Basic approach

The following flowchart illustrates the basic approach for performing a guide word analysis:



Example

The table on the following page includes example documentation of a guide word analysis.

Limitations

- Requires that the activity or procedure be well defined and documented
- Is rigorous and thus time consuming
- Requires trained personnel to conduct the study

Example guide word analysis documentation

Item Number	Deviation	Causes	Consequences	Safeguards	Recommendations
1.0 STEP - REVIEW APPROPRIATE DOCUMENTS, CHECK LOGS, ETC.					
1.1	Missing		No missing steps were identified		
1.2	Skip	Communication barriers with foreign languages Many inspection agencies on board (immigrations, customs) that do not allow adequate time to communicate expectations Time constraints on vessels trying to leave port quickly with pressure to perform rapid inspection/test	Potential to skip later steps because Coast Guard expectations are not communicated to the crew, creating the potential for accident/injury or loss of commerce Potential for inexperienced crew to perform the test, with the potential for accident or injury later in the test Potential for loss of commerce due to delay in passing the inspection/drill Vessel may be held to an inappropriate standard (i.e., drill is not conducted for the correct vessel)	Flexibility of the Coast Guard to work with portions of the crew, so that other portions of the crew can work with other agencies Standardized Coast Guard expectations that are conducted/communicated very frequently Minimum of two Coast Guard staff members, with at least one being well trained	
1.3	Part of	Same as skip			
1.4	More	Same as skip			
1.5	Less	Same as skip			
1.6	Out of Sequence	No consequence of interest if performed before the drill Same as skip if performed after the drill			